Patent Application

Of

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For

COMPACT WAFER HANDLING SYSTEM WITH SINGLE AXIS ROBOTIC ARM AND PREALIGNER-CASSETTE ELEVATOR

CROSS REFERENCE

The present application cross references the concurrently filed and commonly owned US Patent Application titled "Compact Pinlifter Assembly Integrated in Wafer Chuck" by Daniel Tran, which is hereby incorporated by reference.

FIELD OF INVENTION

The present invention relates to wafer handling systems. Particularly, the present invention relates to wafer handling systems including a robotic arm, a prealigner, and an X-Y precision positioning stage.

BACKGROUND OF INVENTION

During wafer fabrication, wafers are repeatedly transferred in cassettes between measurement devices for testing and/or monitoring their fabrication progress and the like. The environment in which wafer fabrication, testing and/or monitoring takes place is subjected to stringent standards making environment real estate very cost intensive. For that and other well known purposes it is desirable to perform the required tasks within a minimal footprint. The present invention addresses this need.

Another aspect of economic wafer fabrication is to provide repetitive basic tasks in a reliable fashion with a minimum of infrastructure. Especially, wafer transfer between a cassette, a prealigner and a measurement location is preferably provided with a minimum of mechanical effort. The present invention addresses also this need.

Wafers are commonly stacked in cassettes in relatively loose fashion and are pre-aligned before positioning on the wafer chuck. For that purpose, a variety of prealigners are commercially available. Commercial prealigners have commonly a footprint that is a fractional proportion larger than the wafer itself. Thus, as wafer sizes increase, commercial prealigners increase as well. This puts even more pressure on developing wafer handling systems that are inexpensive and utilize commercially available prealigners without compromising the demands for minimal overall footprint. The present invention addresses this need.

Wafer transfer between cassette, prealigner and wafer chuck is typically performed by robotic arms. In prior art systems, such robotic arms feature multiple joints to provide a required degree of movement freedom for moving and placing the wafers between cassette, prealigner and measurement location. At the same time, the robotic arms have to move with sufficient precision in a tightly controlled fashion in order to provide positioning accuracy and positioning repeatability. Multiple joint robotic arms are consequently expensive and space consuming. Therefore, there exists a need for a wafer handling system that utilizes a simple and inexpensive robotic arm. The present invention addresses this need.

SUMMARY OF INVENTION

A compact wafer handling system provides a single axis rotating robotic arm mounted on a precision wafer positioning stage in combination with a double platform elevator. The positioning stage has a movement range that depends on the wafer size such that the entire wafer area is accessible by a fixed measurement head placed above the stage. The stage has also a wafer chuck for fixedly holding the wafer. Pinlifters are recessed in the wafer chuck and may be raised and lowered for lifting and lowering a wafer.

The elevator provides two platforms. The top platform is configured for receiving a wafer cassette whereas the elevator's bottom platform is configured for carrying a commercial prealinger. The robotic arm is configured in conjunction with a movement range and pinlifters of the X-Y stage. The elevator again is configured and positioned in conjunction with the positioning stage's movement range, the robotic arm's range and the wafer's size such that the overall footprint of the handling system is at a minimum for a given wafer size.

In order to facilitate the single axis robotic arm, an effector is shaped incorrespondence with the pinlifters' ositions on the chuck. The effector has a distal tangential portion with a carrying face for centrally contacting the wafer bottom. The pinlifters are positioned and configured for lifting the wafer above the carrying face in a balanced fashion. The pinlifters are preferably concentrically arrayed on the wafer chuck with at least one spacing being sufficient large such that the carrying face may be moved into central position with respect to the chucks center axis without colliding with the raised pinlifters.

The pinlifters are arrayed at a distance to the chuck center that is slightly larger than the carrying face's size. Consequently, the tangential arm portion may be kept to a minimum. The effector's rotation axis is placed closely to the wafer chuck such that the arm may have a minimum length necessary for the carrying face to reach the chuck center. The minimum size of the tangential arm portion and the arm's overall length

results in a minimum parking space of the robotic arm. The robotic arm is driven by a controlled motor via a timing belt reduction gear for a smooth and precise angular effector movement. The elevator is placed such that the robotic effector may reach with full travel of the positioning stage sufficiently into the cassette and the prealigner as necessary to load/unload and/or prealign a wafer. The elevator has a Z-axis movement range such that the effector may access each level of the cassette as well as the prealigner placed on the elevator below the cassette.

DESCRIPTION OF THE FIGURES

Fig. 1 is a perspective view of a wafer testing device with an effector in chuck loading orientation.

Fig. 2 is a front view of the wafer testing device of **Fig. 1** with the effector in chuck loading orientation.

Fig. 3 is a front view of the wafer testing device of **Fig. 1** with the effector in elevator alignment orientation accessing the cassette.

Fig. 4 is a perspective view from above onto the wafer testing device according to **Fig. 3**.

Fig. 5 is a front view of the wafer testing device of **Fig. 1** with the effector in elevator alignment orientation accessing the prealigner.

Fig. 6 is a perspective view from above onto the wafer testing device according to **Fig. 5**.

Fig. 7 is a perspective view from above onto the wafer testing device with the measurement head assembly being hidden for the purpose of improved visibility. The effector is in chuck loading position with pin lifters in their top position.

Fig. 8 is a first perspective view from above corresponding to the view direction of **Fig. 7** onto a precision stage assembly with attached robotic single axis system. The effector is in chuck loading position with pin lifters in their top position.

Fig. 9 is a second perspective view from above corresponding to the view direction of **Fig. 1** onto a precision stage assembly with attached robotic single axis system. The effector is in chuck loading position with pin lifters in their top position.

Fig. 10 is a left view onto a precision stage assembly with attached robotic single axis system. The effector is in chuck loading position with pin lifters in their top position.

Fig. 11 is a perspective view on the robotic single arm assembly.

Fig. 12 is the robotic single arm assembly cut along a plane through the rotation axis of the effector and substantially symmetric with respect to a radial arm of the effector.

DETAILED DESCRIPTION

In accordance to **Fig. 1**, a wafer testing device **1** may be a well known spectrometer, reflectometer or other well known wafer testing device in which a wafer **10** needs to be moved and positioned with high precision. beneath and relative to a measurement head **42**. In the Figures, the wafer **10** is a representation of a multitude of wafers that may be handled during operational use of the wafer testing device **1**. Hence, where it is referred

in the following to wafer **10** any single or multiple equally sized wafer(s) may be considered as appropriate and as it may well be appreciated by anyone skilled in the art.

The wafer testing device **1** may have a housing **11** combined with a base **2**. The housing **11** may have any suitable configuration for providing structural support and for integrating additional well known components such as, for example, electrical and other supply devices, control computers and other devices that are well known parts of optical measurement devices.

The base **2** has preferably a horizontal base plate **21** and vertical base plate **22**. The horizontal base plate holds a measurement assembly **4** which may include a head carrying arm **41** and a measurement head **42**. The scope of the invention is not limited to a particular configuration of the measurement assembly **4**. The scope of the present invention includes embodiments, in which a measurement assembly is held within the wafer testing device **1** in any other fashion besides that exemplarily depicted in the Figures.

Attached to and carried by the horizontal base plate **21** is a stage system **3** including for example a high precision linear X-stage **31** and a high precision linear Y-stage **32**. X-stage 31 and Y-stage 32 may be combined in a single commercially available device. On top of the stage system **3** is a well known chuck **33** for receiving and fixedly holding the wafer **10** during measurement. The chuck **33** may have concentrically embedded pinlifters **34** for lifting and lowering the wafer **10** with respect to the chuck **33**. The stage system **3** provides a movement range and a positioning accuracy such that a predefined area of the wafer **10** may be accessed for measurement and positioned with an accuracy required by the measurement process employed by the wafer testing device **1**.

The scope of the invention includes embodiments with a single linear precision stage, which may be the Y-stage **32**. In such alternate embodiments, the linear X-stage **31** may be substituted by a precision rotary stage as may be well appreciated by anyone skilled in the art.

The stage system **3** further includes a robotic single axis system **5** for transferring the wafer **10** in combination with an elevator **7** between the chuck **33**, a cassette **6** and a prealigner **8**. The robotic single axis system **5** includes an assembly plate **51** attached to the X-stage **31**. The assembly plate **51** holds a rotatable effector **52**, a motor **53**, a reduction gear **54** and a vacuum supply **55**.

The vertical base plate **22** features vertical guides **23** that correspond to elevator guides **74** which are attached to and/or part of an elevator frame **75**. Fixed to the elevator frame **75** via platform supports **73** are also a cassette platform **71** and a prealigner platform **72**. The cassette platform **71** is configured for receiving and positioning the cassette **6** and alternating multiple representations of it in a well known fashion. The cassette **6** has multiple wafer stacking positions **61** as is well known in the art for carrying a number of wafers such as wafer **10**. The prealigner platform **72** is configured for carrying and fixedly holding the prealigner **8**. The elevator **7** is actuated by well known driving means such as, for example an electromotor and a thread spindle.

As shown in **Fig. 2** and in the exemplary case of employed X-stage **31** and Y-stage **32**, the X-stage **31** may have an X-travel along a linear precision axis **AX** and the Y-stage **32** may have a Y-travel along a linear precision axis **AY**. Axes **AX** and **AY** are preferably perpendicular to each other. The linear precision axis **AX** may be substituted by a precision rotation axis **PR** of the chuck **33** in case the X-stage **31** is substituted by a rotating stage. The pinlifters **34** are moveable along a dual positioning axis **DP** between a top position and a bottom position. The effector **52** is rotatable around a handling rotation axis **RA** between a chuck loading orientation and at least one elevator alignment orientation. The elevator is actuated along a vertical gross postioning linear axis **VA**. The prealinger **8** has a prealigner operating axis **PA** which is fixed with respect to the elevator **7**. The cassette **6** is positioned with respect to the elevator **7** such that a wafer stacking axis **SA** of the cassette **6** is in a predefined position. The cassette platform **71** is preferably configured for receiving and positioning the cassette **6** such that the stacking

axis **SA** is substantially collinear with the prealigner operating axis **PA**. In that case there is only a single elevator alignment orientation for the effector **52**. The wafer **10** is stacked within the cassette **6** such that the wafer center substantially coincides with the stacking axis **SA**. The wafer stacking levels **61** have a stacking pitch **SP**. Cassette **6** may be replaced by another equally configured cassette during the operational use of the wafer testing device **1**.

The chuck **33** has a wafer holding face **331,** which defines an operation level **OL** at which the wafer **10** is positioned with its bottom surface during operational measurement of the wafer testing device **1**. The operational measurement is preferably provided in closest proximity to the wafer top surface defining a certain head clearance **HC** between the operation level **OL** and the bottom face of the measurement head **42**. The robotic single axis system **5** is configured to provide loading and unloading of a wafer **10** to and from the wafer holding face **331** on a loading level **LL** within a minimum head clearance **HC** of about 1.25inches plus an exemplary wafer thickness of about 0.75mm for a wafer **10** having a diameter of about 300mm.

Figs. 3, 4 show the wafer testing device **1** during loading of wafer **10** from its stack position with the cassette **6** onto the effector **52**. Y-stage **32** is actuated and positioned approximately at one end of its Y-travel close to the elevator **7** after the effector **52** is rotated around its handling rotation axis **RA** into its first elevator alignment orientation. The cassette **6** is positioned on the cassette platform **71** such that a distal carrying face **522** (see **Figs. 8, 9, 12**) interferes the stacking axis **SA** in its first elevator alignment orientation. The height of the wafer **10** reduces the stacking pitch **SP** to a stacking clearance **SC** within which the effector **52** has to fit with its effector height **EH**. Consequently and in compliance with elevator positioning tolerances the effector height **EH** is selected to avoid contact with the wafer **10** and/or other stacked wafers during its movement into and/or out of the cassette **6**.

The wafer **10** may be unloaded from the cassette **6** by a lowering of the elevator **7** such that the wafer **10** is contacting the carrying face **522** and the wafer's **10** weight is shifted

from the corresponding stacking position **61** onto the effector **52**. A vacuum applied to the carrying face **522** may assist in holding the wafer **10** onto the effector carrying face **522**. The cassette **6** may be loaded/unloaded along loading direction **LC**, which is preferably linear. In the preferred embodiment, the cassette **6** is positioned on the elevator **7** such that the loading direction **LC** is substantially parallel to the linear axis **AY**. The wafer **10** is consequently moved out of the cassette **6** via the actuated Y-stage **32** traveling towards its distal travel end away from the elevator **7**. Likewise, loading the wafer **10** into the cassette **6** is performed by reversing the steps described in this paragraph.

Similar to the teachings of **Figs. 3** and **4**, the wafer **10** may be temporarily inserted into the prealigner **8** along the prealinger loading direction **LP**, as is illustrated in **Figs. 5** and **6**. Here, the effector **52** may be brought into a second elevator alignment orientation where the carrying face is brought into interference with the prealigner operating axis **PA**. There, the prealigner **8** may perform a well known prealignment of the wafer **10**. This may be optionally accomplished by an assisting vertical movement of the elevator **7** to induce a relative vertical movment of the wafer **10** with respect to the prealigner **8**. In the preferred embodiment, loading directions **LC** and **LP** are substantially collinear. The terms loading directions **LC** and **LP** are introduced solely for the purpose of explaining the working concept of the present invention without any limiting effect on cassette **6** and prealigner **8**. As may be well appreciated by anyone skilled in the art, cassette **6** and prealinger **8** may be alternating loaded/unloaded in any suitable fashion and corresponding with eventual particularities of cassette **6** and prealinger **8**.

Figs. 4 and **6** illustrate the tight spatial conditions that exist during access of cassette **6** and prealigner **8** as a consequence of keeping the Y-travel to a minimum defined by the operational measurement access of the wafer **10**. All involved components, such as assembly plate **51**, elevator guides **74**, platforms **71**, **72** as well as positions of cassette **6** and prealigner **8** with its access slot **81** and its front **82** have to be adjusted to each other to avoid collision during the accessing of the cassette **6** and the prealigner **8**. In the exemplary embodiment depicted in the Figures, cassette **6** and prealigner **8** are positioned

on the elevator **7** such that their respective cassette loading axis **LC** and prealigner loading axis **LP** are substantially parallel to the linear axis **AY**. First and second elevator alignment orientations are thereby substantially the same.

The scope of the invention includes embodiments in which one or both of the loading axes **LC**, **LP** are aligned with a virtual loading axis that may be composed of a combined movement of the affiliated components around at least two of axes **AY**, **RA**, and **AX**. In that case, the travel of the wafer **10** along the loading axes **LC**, **LP** may be extended beyond the travel of a single affiliated device. For example, a virtual loading axis may be defined that is in a 45 degree to the axes **AX** and **AY**. In that example, the loading travel of the wafer **10** along the virtual loading axis may be the square root of the sum of each of X-travel's and Y-travel's square. Elevator **7** may be accordingly configured and positioned together with the cassette **6** and prealigner **8** as may be well appreciated by anyone skilled in the art.

In **Figs. 7** and **8**, the effector **52** is again shown in its chuck loading orientation. After the wafer **10** is taken from the cassette **6** and prealigned in the prealigner **8**, the wafer **10** may be loaded onto the wafer holding face **331**. For that purpose, pin lifters **34** are brought into top position where their top faces **341** are above the loading level **LL**. During the movement of the pinlifters **34** into their top position, the wafer's **10** bottom is contacted by the top faces **341** and consequently the wafer **10** lifted off the carrying face **522**. At that time, any vacuum is released from the interface between carrying face **522** and wafer **10** bottom. Once the wafer **10** is fully supported by the pinlifters **34** and cleared off the carrying face **522**, the effector **52** may be rotated into a parking position preferably within the lateral boundaries of the assembly plate **51**.

The interaction between pinlifters **34** and effector **52** is warranted on one hand by a collision free movement of the pinlifters **34** between their bottom and top position while the effector **52** is in chuck loading orientation. On the other hand, the effector **52** is shaped to be rotated freely between the pin lifters **34** raised to their top position. For that purpose, the effector **52** features a tangential distal portion **521** laterally protruding at the

end of the effector's **52** radial arm portion **528**. The distal portion **521** is approximately tangentially oriented with respect to the effector's **52** rotation axis **RA**. Particularly, the inside contour **5212** of the distal portion **521** is shaped to remain at a minimum distance to the corresponding pin lifter during effector **52** rotation. Consequently, the carrying face **522** may be brought into interference with the chuck's **33** center axis **CA** for a centered placement of the wafer **10** and the effector **52** may be freely removed while the wafer **10** is resting on the top faces **341**. In case of an employed precision rotating stage, the center axis **CA** is the rotating axis **PR**.

Once the effector **52** is rotated out off the lateral boundaries of the wafer **10**, the pin lifters **34** may be gradually lowered until the wafer **10** comes in contact with the carrying face **331**. Loading from the wafer holding face **331** onto the carrying face **521** is performed in reverse order of the steps described for unloading the wafer **10** from the effector **52** onto the holding face **331**.

To keep the effectors **52** stiffness to a maximum and the effector's **52** parking space to a minimum, the tangential distal portion **521** is preferably kept to a minimum. For that purpose, the radial spacing of the pin lifters on the chuck **33** is at a distance such that the circumferential spacing provides for a sufficient gap such that the tangential distal portion **521** may be inserted with a sufficient width. In a preferred embodiment and for a 300mm diameter wafer **10**, the radius of 3 or 4 concentrically and substantially equally arrayed pin lifters **34** is about 1.75 inches.

Actuation and positioning of the pinlifters **34** may be accomplished in any well known fashion or by a compact pinlifter assembly described in the concurrently filed US Patent Application titled "Compact Pinlifter Assembly" by Daniel Tran, which is hereby incorporated by reference.

To optimize the clamping action initiated by the vacuum in the interface between carrying face **522** and wafer **52** bottom, the carrying face may extend onto the radial arm portion **528**. Vacuum grooves **523** are embedded in the carrying face **521** for an even

vacuum distribution from the access holes **524** across the carrying face **521**. Extending the area of the carrying face **521** proportionally increases the contact pressure and friction clamping in the interface for a given vacuum.

As is additionally shown in **Figs. 9, 10**, the robotic single axis system **5** is configured to fit into the tight spatial envelop defined by the spatial constraints described under **Figs. 4** and **6**. At one hand all involved elements are fitted within the lateral boundaries of the assembly plate **51**. The controller motor **53** and reduction gear **54** are fitted adjacent and within the height of the X-stage **31** and preferably within the loading level **LL**. The reduction gear **54** utilizes preferably timing belts **541** for a smooth and vibration free reduction of the motor's **53** rotational speed. For a 300mm diameter wafer **10,** a robotic single axis system **5** may fit within a concentric envelop **CE** to the chuck **33** having a maximum diameter of 21 inches while the effector **52** is in parking position.

In **Figs. 11** and **12**, the robotic single axis system **5** is shown independently as it may be utilized for upgrading a commercially available combined X-Y precision stage. The assembly plate **51** has a central cutout arc **59** for a substantial concentric fit around the chuck **53**. The assembly plate **51** has overall an approximate C-shape to fit around the circular chuck **33** and for being attached on top of the combined X-Y stage. A rotation sensor **542** may be employed for recognizing the orientation of the effector **52**. The rotation sensor **542** is preferably actuated by the effector's **52** rotatable mounting shaft **527** as depicted in the Figures. A vacuum line is integrated in the effector **52**, which includes a horizontal portion **525** propagating within the radial arm between the access holes **524** and a concentric portion **526**. The concentric portion **526** propagates along the mounting shaft **527** where it terminates at a non rotating hub **543**. In that fashion, a vacuum is communicated from the vacuum supply **55** to the carrying face **522**.

The carrying face **522** is slightly raised above the top of the remaining effector **52**, such that an eventual deflection of the effector **52** due to the wafer's **10** weight does not compromise the snuggle contact between the wafer **10** bottom the carrying face **522**. The effector **52** may be fabricated from highly stiff material such as carbon enforced

compound material. The compact configuration of the robotic single axis system **5** provides for a minimum real estate consumption.

Overall the wafer handling system of the present invention provides for a highly precise positioning with a minimum of controlled axis movement. Due to the low number of axis by which the wafer is manipulated, the wafer's **10** transfer may be accomplished in a reliable, quick and efficient manner. Well known computerized controlling means may be employed for controlling the affiliated components.

The present invention includes embodiments, in which the prealigner **8** is a non commercial device specifically configured in conjunction with the elevator **7** and its above taught design particularities as may be well appreciated by anyone skilled in the art.

Accordingly, the invention described in the specification above is set forth by the following claims and their legal equivalent: